Maybe the individual has been running on a downhill at speeds faster than 5:20/mile, or across a significant grade. Check the runner's shoes for a failed gizmo or breakdown. These are potentially hazardous circumstances and combinations.

Again, check the athlete's conformance for an excessive Q angle, bowed legs, or a leg length difference. Look for overdeveloped and tight quadriceps, as well as limited hip extension. The individual may have weak hamstrings, lower abdominals, gluteals, internal and external rotators of the hip, and vastus medialis muscles. Videotape and view the runner's biomechanics from several angles. Is there excessive medial or lateral rotation of the upper and lower legs? Is there excessive motion at the knee? Does the athlete exhibit a whip?

A hip injury is often deep and difficult to locate or isolate with ice or heat therapy. The best medicine is prevention. Avoid the high-risk conditions mentioned above. An individual with a minor injury should always conduct a pre-warm up and full range of motion exercises before running. The injury will normally respond to strengthening the internal and external rotators of the hip. However, do not conduct these exercises to the point of eliciting pain. Discontinue the exercise before the area becomes fatigued and pain is experienced. If an athlete pushes things to the point of causing pain, then the individual may be taking two steps forward and one step backwards. Given a hip injury, easy bicycling can be of help, particularly during the early stages of rehabilitation. Another beneficial exercise for strengthening and healing the hip area is skating at moderate speed with a conservative technique. Swimming is normally beneficial, but it can sometimes aggravate a hip injury, thus an individual should first test matters and then be careful to exercise in moderation.

Sciatic Nerve

The sciatic nerve is actually composed of several nerves, which emerge both from the lumbar vertebrae and the sacrum, at L4, L5, and S1-4. A sciatic nerve problem generally manifests itself as a pressure, pain, or numbness in the lower back, sacrum, or buttocks. Most frequently, sciatica is felt in the left or right buttocks a couple of inches above the ischial tuberosity, or so-called "sit bone." The pain will often radiate down the back of the leg. If sciatica begins during training, the athlete should cease the activity immediately in order to catch it early. If the individual stops and conducts suitable therapeutic exercises, he or she might be back in action the next day. However, a runner who fails to take appropriate measures could become seriously injured and put themselves out for a long time. Normally, in healthy young athletes with no history of a lower back or pelvic injury, sciatic nerve problems can generally be traced to excessive forward, that is, anterior pelvic tilt, a displaced sacroiliac joint, or a muscle spasm.

Gather the necessary information to determine what happened and when. Did the sensation or injury develop following a workout? Perhaps the individual had a long aircraft flight, was sitting slumped on a sofa for several hours watching television, or slept in a strange position? If athletes sleep on their back in too soft a bed, then the sinking of their buttocks into the mattress can induce anterior

pelvic tilt. Sleeping on a firm futon or placing pillows behind their knees can reduce anterior pelvic tilt. Even if athletes sleep on their side, a too soft or broken down bed can still cause their lower back to be misaligned. Athletes who normally sleep on their side might want to place their arms around a pillow positioned parallel to their torso. Otherwise, some might rotate too much at their shoulders, and that could place a lot of stress on their lower back. If athletes habitually sleep on their side, then placing a pillow between their knees might also help. Again, athletes should sleep on a firm futon rather than too soft a bed. In this regard, the Australian coach Percy Cerutty suggested that athletes sleep on wooden bunks to improve their posture and vital capacity.

Check the individual's anatomical conformance, particularly in the back and pelvis. Compare the hip height of each iliac crest, and check for a leg length difference. Look also for a functional leg length difference due to a breakdown in one of the athlete's shoes. Is the athlete running on roads with a grade? Again, running across a five-percent grade can easily produce an effective leg length difference of 1/4-inch.

The most common problem is that the pelvis has tilted too far forward, that is, anteriorly, and is causing a nerve to become impinged in the lower back (See Figure 9.20). Generally, this is due to the athlete's quads being too strong and too tight relative to weak hamstrings and lower abdominals. Initially, an effective rehabilitation exercise could be to lie flat on your back on a hard, flat floor for about 30 minutes. At first, this may feel uncomfortable due to pressure being placed on the sacrum, and the small of your back might be in an over-extended position. However, as anterior pelvic tilt is reduced, your lower back will relax and flatten, and the pressure on the sacrum will re-distribute to the larger buttocks. During this exercise, you might hold your lower back in a flattened position and then relax, or alternately raise and hold each knee to your chest, and then relax. Once you have restored the pelvis to its neutral position, strength training of the appropriate muscle groups needs to be conducted in order that proper posture be maintained. However, if an individual has any reason to believe that he or she could have a congenital defect or injury to the lower back, a medical professional should be consulted before attempting these exercises.

Rehabilitative training includes strengthening the hamstrings, vastus medialis, lower abdominals, and improving hip extension. All of these can be accomplished by doing walking squats. Further, athletes often strengthen their upper abdominals, but tend to neglect their lower abdominals. Exercises that strengthen the lower abdominals include straight and bent knee sit-ups on an incline board, and L-sits. In addition, athletes can lie on their back and perform a bicycling action while sweeping their legs close to the floor in order to work their lower abdominals.

Runners tend to get sciatica when they suddenly and dramatically increase their mileage. Soreness in the lower back can sometimes be a false alarm for sciatica. Instead, it may be associated with the origins of the iliopsoas muscles, particularly the psoas major, which is a powerful flexor of the hip. An actual sciatic nerve problem can arise if the piriformis muscle goes into spasm, impinging the

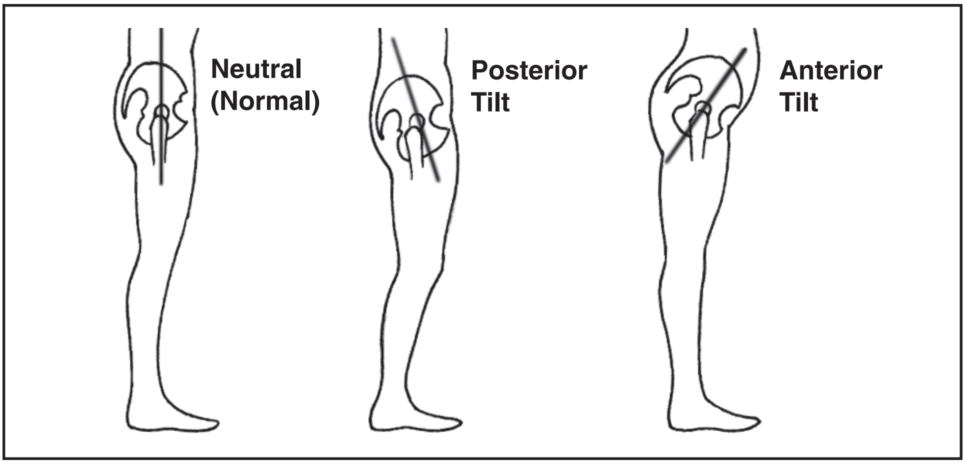

FIGURE 9.20—Pelvic tilt

sciatic nerve. Exercises that work the piriformis can often quickly relieve the spasm causing the impingement. Sciatica can also arise from a displaced sacroiliac joint. If the sacrum or ilia shift too much they can become slightly misaligned. A qualified physical therapist can often correct the problem via manipulation. Also, certain exercises can help to stabilize and restore the correct orientation.

An otherwise healthy individual with no history of back injury, may perform the dead lift exercise, using a barbell with light weights. The dead lift can often clear up the warning twinge or spasm from a developing sciatic problem that is being caused by a slightly displaced sacroiliac joint, or piriformis muscle that has gone into spasm. This exercise should only be considered if the injury is not advanced. Find someone who knows proper technique and learn how to perform the dead lift correctly. The barbell should be grasped with one palm turned in and the other out. The barbell should rest against the athlete's shins and be dragged upward, along the front of the shins, then across the knees and quads as if it were glued to them. The athlete's head should face forward and upward during the lift. It is important to use a weight belt when performing this exercise. The movement to the up position should finish with a pelvic thrust to prevent the pelvis from rotating forward. And the athlete's back should not be flexed relative to the pelvis—both should remain relatively straight and aligned. The movements then take place mostly between the legs and the pelvis, not the pelvis and the back. The entire exercise should be done slowly, taking approximately a count of six to the up position. On reaching the up position, the athlete should either hand off or drop the weights. This can be done using rubber weights and dropping them on an elevated platform, or by dropping the weights into sand. Under no circumstances should the athlete return to the start position, bend over, or lower the weights. It is important that concentric muscle contractions take place, not eccentric. If the athlete instead lowers the weights while returning to the start position, the net positive effect will generally be zero, or the problem could actually become worse.

The athlete should first attempt an easy effort of six to 10 repetitions with light weight, then wait several hours or even a day to judge the reaction. If the response is positive, then add a little more weight and conduct two or three sets of 10 reps. Wait a day, and then repeat the session. If the problem indeed involves a spasm of the piriformis muscle and/or displaced sacroiliac joint, the athlete will often feel that something positive has been accomplished within a few minutes, and certainly within one hour of the exercise. If an athlete later feels a twinge coming on and heads it off with a couple of sets, it will often be gone within a few hours. However, an individual who chooses to ignore the warning twinge and runs anyway will risk more serious injury.

For healthy young athletes, the author has found this exercise to be the single most effective technique for heading off a sciatic problem. It works the hamstrings, but also the gluteus minimus, medius, and the piriformis muscles. The exercise causes these muscles to shorten, thus stabilizing and causing the pelvis to tilt backward into correct position. When these muscles contract, the practical effect is to shorten the distance between their origins and insertions, and this reduces anterior pelvic tilt. A physical therapist might refer to this exercise as a muscle energy or stabilization technique, whereas a coach or trainer would simply hold this to be a part of a balanced strength training program.

Compartment Syndrome

Distance runners rarely experience compartment syndrome. Those who do will not likely recognize what is happening or know what to do about it, and that can be dangerous. In this condition, a muscle (perhaps developing too rapidly) outgrows its confining muscle sheath and becomes constricted during exercise. As the muscle fills with blood, becoming hot and pumped during exercise, it enlarges and begins to cut off its own blood supply. The symptoms are rigor and pain resembling a muscle cramp. The affected muscle can become hard to the touch, as if it were being voluntarily flexed. If this occurs, the athlete should stop training immediately, and then ice and elevate the affected part. If the muscle does not relax within a few minutes, the athlete must get to a physician as quickly as possible. Get the athlete to an emergency room STAT by dialing 911. If left untreated, the loss of circulation can kill the affected muscle tissues. Sometimes surgery is needed to relieve the pressure by slicing the muscle sheath. This is not a problem, and in time it will normally repair itself. Young athletes going through a growth spurt who are beginning to exercise heavily can be susceptible to this syndrome. Another group that may experience this problem are those using illegal hormones and steroids, because these substances induce abnormally rapid gains and losses of muscle mass. Play with matches and you will probably get burnt.

Stress Fractures

It takes bone tissue at least five to six weeks to adapt to a new level of training stress. Dramatic changes in training quantity or quality can place an athlete at risk. Bone tissue is not a perfectly rigid material. Instead, it bends or flexes to

some degree when loaded. The long bones of the legs are especially vulnerable to rotational (or torsional) loading. As the foot pronates and rotates inward, the tibia is loaded and also rotates inward. At the same time, the femur rotates outward. These torsional loads on the long bones can result in stress fractures.

Sometimes the precipitating event is damage to the bone surface (or periosteum) where a tendon originates. A lot of energy is conducted through the point of origin, and sometimes the site is not adequately robust. With continued loading, a hot spot or stress fracture can develop. Hot spots can be observed immediately using Magnetic Resonance Imaging (MRI), but this procedure is expensive and sometimes unavailable. A stress fracture can sometimes take seven to 14 days to appear on a conventional X-ray. Often, if a stress fracture is present, a tuning fork placed upon the affected long bone will elicit pain. An athlete with a stress fracture will need at least five to six weeks to recuperate. However, depending on the age of the athlete, and the location, type, and severity of the injury, it can take as long as 12 weeks for the bone to mend. The most common stress fractures suffered by runners are to the metatarsals, sesamoids, tibia, and fibula. Fractures to the femur, pelvis, or vertebrae do happen, but these are relatively rare. Women more frequently experience stress fractures. This is due in part to their lighter bone structure, but it can sometimes also stem from an eating disorder.

Eating Disorders

If a coach is training a young female athlete conservatively and she does not appear to have faulty technique or motion control problems, yet she suffers reoccurring injuries (such as shin-splints or stress fractures of the tibia, fibula, or metatarsals of the foot), then the coach may actually be seeing the symptoms of an eating disorder. Exercise creates a higher demand for calcium, phosphorus and other essential minerals. If an athlete is not eating adequately or keeping food down, these minerals will be drawn from bone tissue. After ruling out other possibilities, the coach should seriously consider the possibility of an eating disorder, and then refer the athlete to professional help. As a coach, do not attempt to also assume the role of a clinical psychologist or medical doctor regarding arousal addiction and eating disorders. Those two hats present a potential conflict of interest. This condition is potentially life-threatening, and a coach is not qualified to practice in this area unless trained as a medical doctor or clinical psychologist.

Muscle Strains

The best medicine is an ounce of prevention. An athlete can avoid muscle pulls by maintaining well-conditioned, flexible muscles, and adopting sound training practices. However, if a muscle strain does occur, the affected area should be iced and elevated immediately. Do not apply heat or massage until the next day, or perhaps even the second or third day—that is, until the bleeding and inflammation has stopped and the healing process begun. After the desired range

of motion has been restored, the fastest way to rehabilitate an injured muscle is with easy and well-controlled strength training. If an injured athlete does little or no rehabilitative activity, then even after having rested for a week or two he or she may still be at square one. However, with a suitable rehabilitation program, an athlete will normally be back in training much sooner, and the injury will heal better. Given a serious muscle strain, seek out the assistance of a medical doctor and a qualified physical therapist.

In this chapter a number of common orthopedic injuries have been briefly addressed. However, recognize that the most frequent injury suffered by athletes is not to their physical structure, but rather to their metabolism as the result of over-training (See the discussions in Chapter 1 and Chapter 6). Entire books have been written on the subject of athletic injuries—and also about running shoes. This chapter has touched on some important points, but not every possible topic of interest could be addressed in detail. Again, when you have questions about your health or that of someone for whom you are responsible, always consult a qualified medical professional such as a doctor, podiatrist, or physical therapist. Also, recognize that many knowledgeable and sincere individuals—whether researchers, coaches, or medical professionals—will sometimes differ in their opinions and past experiences. We are all unique individuals. And no two sets of circumstances are ever identical. Listen to your body, and in the words of the Delphic Oracle: **Know Thyself.**

> ***I went to Penn State and asked the people who were rating shoes about balance and spring. Well, they didn't know what I was talking about. How can they rate shoes if they don't know even the most elementary things? They're not experts.***
>
> —Arthur Lydiard

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PART III

Special Considerations for Distance Runners

PHOTO 10.1—E. C. "Ned" Frederick at his home in New Hampshire, 2000.
Photo courtesy of Ned Frederick.

CHAPTER 10

SHOE WEIGHT AND MECHANICAL EFFICIENCY

The weight and mechanical efficiency of an article of footwear can significantly impact athletic performance, particularly at national and international levels of competition. How much do your track spikes and racing flats weigh? How much does additional shoe weight cost a distance runner in terms of performance? How much does the mechanical efficiency of a shoe or running surface affect athletic performance?

Shoe Weight

E.C. (Ned) Frederick is probably the most knowledgeable person in the United States on this subject. Ned found that 100 grams added to each shoe equated to an increased energy cost of 1.2% of an individual's oxygen uptake while running at racing speeds (Frederick, Daniels, Hayes, 1984). How does this translate into ounces? Given 28.35 grams in an ounce, 100 grams would roughly equal 3.5 ounces. Accordingly, 1.2% divided by 3.5 ounces equals .342% as the approximate energy cost per ounce of additional shoe weight.

After reviewing the methodology of various studies on this subject, the author estimates that the actual energy cost of carrying an additional ounce on a shoe would be a bit higher in the practical application. Rather, it would affect performance by about .5% of VO_2 maximum. The reason being that in a lab setting weight can simply be added to a shoe, but additional weight in a commercial product is often associated with disadvantageous changes in the structure and function of athletic footwear. Further, most of these studies were conducted on level treadmills, which can solicit changes in a person's running technique, reducing the amount of work in hip extension. This can be overcome by inclining a treadmill to require greater effort during hip extension, but this introduces another variable.

With the use of the tables found in *Oxygen Power* (Daniels and Gilbert, 1979) and a calculator, the energy cost of carrying an extra ounce of weight on an athletic shoe can be estimated. A change in shoe weight of one ounce (corresponding to a .5% change in oxygen uptake or VO_2 maximum) is worth at least approximately:

- 1 second in a 1,500 meters performance of 3:35
- 4 seconds in a 5,000 meters performance of 13:20
- 8 seconds in a 10,000 meters performance of 27:45
- Over 30 seconds in a marathon

These are large margins in national or international competitions.

The spikes that Bill Bowerman made for Steve Prefontaine weighed between three and four ounces. Commercial size 9 track spikes or racing flats commonly weigh between 6.5 to 7.5 ounces, but clearly, it is possible to have equally functional and durable footwear weighing between 4.0 and 5.5 ounces. It is sometimes possible to modify a commercial shoe and reduce shoe weight by two full ounces, thus the time savings shown above could potentially be doubled.

Mechanical Efficiency

In addition to its weight, an athletic shoe's mechanical efficiency should also be considered. Athletic shoes function as a spring, thereby storing and returning energy over time. But they also act as a dampener, undergoing hysteresis and transforming mechanical energy into heat. The characteristic ratio of the spring and dampening qualities of most athletic shoes is about 50/50, but can range from 40/60 to 60/40. Often, the price for using a stiffer spring is greater transmission of shock and vibration, and reduced cushioning effects. However, at times an athlete may wish to sacrifice cushioning in favor of maximizing mechanical efficiency. For example, sprinters are sometimes wise to remove soft insoles from their track spikes when competing on elastomeric track surfaces, because cushioning is associated with deflection, and deflection takes time. Moreover, all things being equal, reducing the elevation of a sprinter's foot relative to the track surface will result in less time and energy being lost to rotation and stabilizing movements.

Some racing flats with non-homogenous shoe sole compositions can provide good cushioning and high mechanical efficiency. For example, some shoes use a relatively soft foam material in the lateral rear corner, or "rearfoot strike zone," but include stiffer foam materials on the medial side and in the forefoot area. In fact, some athletic footwear can actually provide an energy savings by reducing the oxygen uptake used in protecting the runner from shock and vibration—a phenomenon known as the "cost of cushioning." Frederick was able to demonstrate an improvement in performance corresponding to a change in oxygen uptake of 1.3% in subjects running at racing speeds while using a NIKE AIR® racing flat (Frederick, Clarke, Larsen, and Cooper, 1983). For athletes capable of running 2:09 in the marathon, a 1.3% improvement of their oxygen uptake would result in a time saving of approximately 90 seconds—thus a performance of 2:07:30 would be possible. Obviously, increasing the mechanical efficiency of athletic shoes can result in substantial improvements in athletic performance.

The question of mechanical efficiency and the "cost of cushioning" can also influence efforts to reduce shoe weight. Stripping a track spike or racing flat down to about four ounces can work well for cross-country and road race events shorter than 8,000 meters. However, because of the increased stress placed upon the body when cushioning is reduced, extremely light shoes can be a risky proposition at distances between 10,000 meters and the marathon. The ideal racing flat for short distance events may be unsuitable for longer distance events because it can permit greater transmission of shock and solicit biomechanical adjustments that diminish performance and delay recovery from exercise.

Springs and Performance

The current USATF Rulebook, Apparel Rule 71 (essentially the same as IAAF Rulebook, Rule 143) reads as follows:

> a) A competitor may compete in bare feet or with footwear on one or both feet. The purpose of shoes for competition is to give protection and stability to the feet and a firm grip of the ground. Such shoes, however, must not be constructed so as to give the competitor any additional assistance, and no spring or device of any kind may be incorporated in the shoes. A shoe strap over the instep is permissible.

However, all of the materials and devices presently used in the soles of athletic footwear—including rubber, foam, thermoplastic, carbon fiber composites, and gas-filled bladders—comprise both a spring and a dampener. One question would concern the mechanical efficiency provided by a given component in an article of footwear, and the potential competitive advantage conferred by so-called spring devices. Several variables greatly complicate this question, such as the body mass and characteristic running technique of a given individual. Insofar as a shoe provides either too stiff or too soft a spring for the needs of a distance runner, it will not provide the wearer with advantageous performance. Further, the suitability of a shoe including a spring also depends on the rate of loading, thus the particular speed an individual is running. To achieve optimum mechanical efficiency, an athlete requires a softer spring when running slowly, but a stiffer spring when running at faster speeds.

Athletic shoes are not all the same, and the differences can significantly impact performance. A single generic commercialized product cannot provide all athletes with equal mechanical efficiency. No two footwear products, or individuals are alike. Most commercial athletic shoes have been developed and wear-tested for a generic size 9 male weighing between 140 and 165 pounds. Accordingly, athletes differing in body mass, running technique, and speed will normally experience differences in their mechanical efficiency and running economy when using the same make and model of footwear. Since the geometry and stiffness of conventional footwear cannot be customized, it is simply not possible for everyone to enjoy an equivalent level of performance. Athletes should experiment with a number of shoes to understand which characteristics provide them with the best results. A promotional athlete is sometimes in the position to order custom footwear. Recognize that the support surface upon which the athlete performs also constitutes a part of the mechanical system. However, the most important part of the mechanical equation is the human body, which normally contributes and manages over 97% of the energy during athletic performance.

When Adidas-Salomon AG approached the IAAF with a track spike incorporating a full-length carbon fiber spring element for possible use by sprinters during the 2000 Olympic games, the IAAF ruled it was permissible. The claimed

enhancement of performance was between one and four percent, roughly corresponding to one second/400 meters (Nielsen, 2000). This was potentially the most significant development with respect to human performance in track and field since the introduction of the modern elastomeric track surface.

However, this was not an entirely new development. Nike, Inc. had previously used a carbon fiber composite element that was visible on the bottom of Mike Powell's long jump spikes during the 1992 Olympic Games. Also, other footwear manufacturers—including Etonic Athletic, Inc., Brooks Sports, Inc., and Mizuno, Inc.—have used like materials in footwear that have been previously commercialized. In particular, Hugh Herr and Igor Gamow are co-inventors on patents directed towards spring elements for use in footwear (U.S. Patents 5,367,790, 5,701,686, and 6,029,374). Moreover, the author has also filed several patent applications relating to selectively removable and replaceable spring elements for use in making customized articles of footwear that can provide an individual with enhanced cushioning, stability, and running economy (See Figure 10.1, U.S. 6,449,878). In brief, the traditional materials and methods of making athletic footwear are presently in the process of transformation and a new paradigm is beginning to emerge (Kerdok, Biewnere, McMahon, Weyand, Herr, 2001, and Herr, Huang, Langman, Gamow, 2002).

It is thus becoming more difficult to provide simple advice on the functional qualities that an athlete should look for in footwear. When searching for a conventional shoe construction, select a product with an appropriate design and cushioning characteristics for optimizing your running technique. Also, select a shoe that dissipates heat well, is relatively lightweight, and provides good traction and overall performance given the anticipated environmental conditions. Again, athletes need to confirm their footwear selection at least three months before a major championship competition. Moreover, for optimal biomechanical adaptations to accrue, distance runners should train at least twice a week in the make and model of footwear that they have selected.

Orthotic Devices

The use of an orthotic (or insert) device can increase efficiency and enhance performance, but only when the overall weight of the resulting shoe remains nearly constant (Clement, Taunton, Wiley, Smart, and McNicol, 1984). The transport of weight at the end of an individual's foot—which can be moving at nearly 50 mph—consumes limited energy. For some athletes, lightweight orthotics for use in their racing spikes or flats can be an essential piece of equipment, as this can save those runners having atypical conformance or motion control problems from injury, and so facilitate recovery from competition. However, regarding the possible beneficial effect of using orthotics upon athletic performance, runners should consider themselves lucky to break even.

Running Surfaces

Surface variations can also dramatically affect the efficiency of the larger mechanical system comprising the human body, athletic shoe, and underlying

US006449878B1

(12) **United States Patent**
Lyden

(10) **Patent No.:** **US 6,449,878 B1**
(45) **Date of Patent:** **Sep. 17, 2002**

(54) **ARTICLE OF FOOTWEAR HAVING A SPRING ELEMENT AND SELECTIVELY REMOVABLE COMPONENTS**

(76) Inventor: **Robert M. Lyden**, 18261 SW. Fallatin Loop, Aloha, OR (US) 97707

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Mar. 10, 2000**

(51) **Int. Cl.**^{7} **A43B 13/28**
(52) **U.S. Cl.** **36/27**; 36/38
(58) **Field of Search** .... 36/27, 28, 30 R, 36/38, 7.8

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(57) **ABSTRACT**

The article of footwear taught in the present invention includes a spring element which can provide improved cushioning, stability, running economy, and a long service life. Unlike the conventional foam materials presently being used by the footwear industry, the spring element is not substantially subject to compression set degradation and can provide a relatively long service life. The components of the article of footwear including the upper, insole, spring element, and outsole portions can be selected from a range of options, and can be easily removed and replaced, as desired. Further, the relative configuration and functional relationship as between the forefoot midfoot areas of the article of footwear can be readily modified and adjusted. Accordingly, the article of footwear can be customized by a wearer or specially configured for a select target population in order to optimize desired performance criteria.

30 Claims, 9 Drawing Sheets

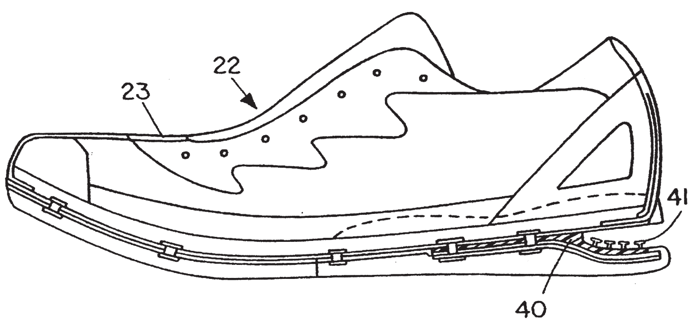

FIGURE 10.1—U.S. Patent 6,449,878

running surface. The most celebrated experiment in this regard being the tuned track at Harvard University (McMahon, Green, 1979). And not all portions of a given track surface are alike. Prior to a track and field competition, the Australian coach Percy Cerutty had the habit of bouncing a golf ball on different areas of the track to determine where the surface was alive and where it was dead.

The elastomeric tracks now available to athletes will generally aid distance performances by approximately .5 to one second/400 meters, whereas they commonly reduce performances in the sprinting events by .1 second/100 meters relative to hard asphalt-like tracks. Different road and cross-country course conditions can also dramatically influence running efficiency. On softer courses, it is sometimes wise to use footwear with firmer cushioning, and vice-versa. Further, athletes should prepare for the type of course conditions and surface footing expected in an upcoming major championship. They will then be able to adapt and optimize their running technique prior to the competition.

Many coaches and athletes never question the possible effects of the weight and efficiency of athletic footwear—or the impact that orthotics and running surfaces have on performance. This is a serious mistake. The practical effect of any one of these variables can be substantial.

> ***If you can doubt at points where other people feel no impulse to doubt, then you are making progress.***
>
> — Chang Tsai

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PHOTO 11.1—Jack Daniels, exercise physiologist, coach, and author, delivering a presentation in 1986. Photo from Victah Sailer / Photorun.

CHAPTER 11

IRON DEFICIENCY ANEMIA

This discussion of iron deficiency begins with several warnings. Iron is poisonous when taken in high doses. Iron supplements are one of the most frequent causes of household poisoning in children. Often, the pills are red and look like candy, and so iron supplements must be stored where children cannot get access. Further, athletes can sometimes lack sufficient iron, but one of the most common genetic disorders is hemochromatosis (affecting .3 to .5% of the population), which causes the affected individual to absorb too much iron (*Cecil Textbook of Medicine*, 1996). Accordingly, it is wise to consult with a physician before initiating any form of iron supplementation. Moreover, in extreme cases of iron deficiency anemia, an individual can require an injection under the care of a physician. Some of the products that have been developed must first be tested at 10% of normal dosage in an emergency room, because individuals can be allergic to the bovine serum containing the iron, and the reaction can cause anaphylactic shock.

Again, whenever iron deficiency anemia is suspected, first consult with a physician. In cases of iron deficiency anemia, the hemoglobin has priority with respect to the available iron. The level of iron stores will need to be determined by testing the serum ferritin because the hemoglobin content will be misleading. The values obtained in a serum ferritin test can vary a greatly from one individual to another. Moreover, an individual can have elevated serum ferritin values due to an inflammatory and infectious disease, or as the result of over-training. When in peak fitness, elite athletes might be wise to perform a serum ferritin test (as well as blood profile, blood lactate threshold and VO_2 max tests), as they would then have a basis of comparison if they would ever suffer a health problem.

In the abstract, the values obtained in a serum ferritin test could be anywhere in the range between 10 to 200 nanograms/milliliter (ml). However, the normal values differ considerably in populations of elite male and female distance runners. Since no definitive study on the subject of serum ferritin test values and distance runners has been published, the information in this chapter may then be of assistance to medical professionals. The author is indebted to Jack Daniels and other coaches for sharing their experiences concerning iron deficiency anemia. Moreover, several relevant references are cited at the end of this chapter.

Male distance runners normally maintain serum ferritin values over 60 nanograms/ml., but many individuals seem to be fine providing that they stay within the range of 30 to 60. When male athletes fall below 30 nanograms/ml., iron deficiency anemia can severely affect their aerobic ability. If athletes are on

the low end of the 30 to 60 nanograms/ml. range, or abnormally lower than their usual profile, they will commonly experience good days alternating with bad days in training. Because of the wide range of individual variation, the serum ferritin test is often given several times in order to monitor an athlete's values. The average value recorded by approximately 30 elite male distance runners tested over several years by Jack Daniels (former exercise physiologist for club Athletics West) was about 60 nanograms/ml. But in order to illustrate the wide range of individual variability, one male 800 meters runner never tested much above 30 nanograms/ml., whereas a 5,000 meters specialist (who perhaps had hemochromatosis) was tested at 200 nanograms/ml.

Female distance runners experience a much higher incidence of iron deficiency anemia. Elite female distance runners are often close to borderline—thus they are generally well advised to take some form of iron supplement. The normal range of serum ferritin for women runners is lower than that of men. If a woman's serum ferritin test reads below 15 nanograms/ml., she will normally be seriously affected by iron deficiency anemia. Somewhere between 15 and 20 nanograms/ml. can be considered borderline and low. Values between 20 and 30 nanograms/ml. can be interpreted as normal. The average value of 30 elite female distance runners studied by Daniels was 26.8 nanograms/ml. (Daniels, Scardina, Hayes, and Foley, 1986). However, he felt that perhaps this group tested lower than normal and something closer to 30 nanograms/ml. might represent a healthier target value. On the other hand, it might be difficult for some female distance runners to attain a value of 30 nanograms/ml., even when taking iron supplements. Given the undesirable side effects of overdoing iron supplements, athletes should not think a higher value necessarily means that they will be healthier or capable of running faster. As long as female athletes test in the mid 20's and feel fine, then their serum ferritin levels are normally a non-issue (Daniels, 1987-1997).

Iron supplements are available in the form of ferrous gluconate or ferrous sulfate. A normal iron supplement dosage is about 150 milligrams/day, but under a doctor's prescription sometimes several times that amount can be taken. An overdose can lead to stomach cramps, constipation, or diarrhea. It is best to take iron supplements right after meals. Further, iron supplements are best absorbed when taken in conjunction with Vitamin C. Free iron in the body also plays a role in the actions caused by free radicals, thus athletes might be advised to take Vitamin E with iron supplements in order to counter possible undesired side effects (Berglund, 1992). They should avoid any form of caffeine within two hours of taking iron supplements, and this would include many soft drinks.

Athletes in torrid climates tend to encounter iron deficiency anemia more frequently since heavy perspiration tends to flush more iron and electrolytes out of their system. Further, athletes running in hard shoes or on hard surfaces can mechanically destroy more red blood cells than athletes training in well-cushioned shoes, or on natural surfaces (Falsetti, Burke, Feld, Frederick and Ratering, 1983, also Dressendorfer, Wade and Frederick, 1992). Shoes or insoles providing conformance including a cupped shape about the heel can also cause less mechanical trauma—including less damage to red blood cells (Jorgensen and

Ekstrand, 1988). Athletes should keep away from petroleum products, whether airborne or in topical applications because these can sometimes induce another form of anemia.

If an athlete's serum ferritin appears normal, anemia can still be present in one of several forms. To determine the nature and extent of the possible disorder, a physician may study a more comprehensive blood profile. One of the significant values is the hematocrit—that is, the percentage of particles in the blood by volume. The hematocrit is largely composed of RBC's (Red Blood Cells). The normal hematocrit range for women is 42 $\pm$ 5%, and for males 47 $\pm$ 7%. The RBC count is another important variable because red blood cells transport the hemoglobin that carries most of the body's oxygen to the cells. The normal count for males is approximately 5,400,000, and for females approximately 4,700,000 cells per cubic millimeter (Jacob and Francone, 1974). Changes in the red blood cells' MCV (Mean Corpuscle Volume) can indicate one of several forms of anemia. A physician can also examine the RET count—that is, the reticulocyte or infant red blood cell count. A change in the rate of RBC production can indicate a disorder, or the death of red blood cells due to an infection. A RET value of .5% indicates a slowing down of production, .5-1.5% the normal range, and 1.5% a speeding up of red blood cell production (Jacob and Francone, 1974). Physicians will also often test for hemoglobin, since it carries over 98% of the oxygen transported by the blood. The normal range for women is 12 to 14.5 grams/100 ml., and for males 14 to 16.5 grams/100 ml. (Martin, 1994). Other hemoglobin values include MCH—that is, Mean Corpuscle Hemoglobin by volume and weight.

Iron deficiency anemia is a relatively rare malady experienced by distance runners. Some athletes might then ask: How do you get it? The story of a high school athlete who became so afflicted can perhaps serve as a lesson for others so that they might avoid making the same mistakes. In the fall, the athlete had been successful in state and national cross-country championships. The individual then competed directly in a winter sport without taking a break. Despite being advised against this, neither the athlete nor the athlete's parents heeded the warning. Success and the need for entertainment can be a dangerous intoxicant. In truth, it had been a long, hard season, and the individual needed the break afforded by a period of post-season recovery. At the same time, the athlete was going through a growth spurt, but did not pay close attention to dietary needs. Moreover, the athlete also pursued an active social life. In short, this individual wanted to have it all.

Half way into the spring track and field season the athlete became tired and performance levels dropped. The runner was advised to see a doctor and have a serum ferritin test. The test came back with an abnormally low value. As a result, the athlete was diagnosed as having iron deficiency anemia, and was then provided with iron supplements. Within two weeks the runner was able to improve by ten seconds in the 1,600 meters, and a short while later managed to win the State Championship. However, the athlete's fitness did not approach the level attained six months earlier. The lesson that life often teaches is that you cannot have it all.

In sum, athletes who ignore their bodies and nature can succumb to iron deficiency anemia. Things do not just happen without a cause. Sometimes, when athletes experience health problems, what their body is really telling them is that they have made a mistake and need to take a break. When faced with adversity, if athletes take the opportunity to reevaluate their physical and mental approach, it might prove to be the significant breakthrough that they really need.

This chapter provides some basic information on iron deficiency anemia. Hopefully, athletes will be able to avoid or identify a potential problem early, and be able to ask some of the right questions. A naturopathic doctor or dietitian might say: “A handful of raisins a day, keeps iron deficiency away.” However, any number of factors can contribute to an anemic condition, and athletes need expert medical attention whenever that possibility arises. Do not despair. Given proper medical care, most cases of iron deficiency anemia can be easily corrected within a relatively short time.

> ***It is on disaster that good fortune perches; It is beneath good fortune that disaster crouches.***
>
> —Lao Tzu

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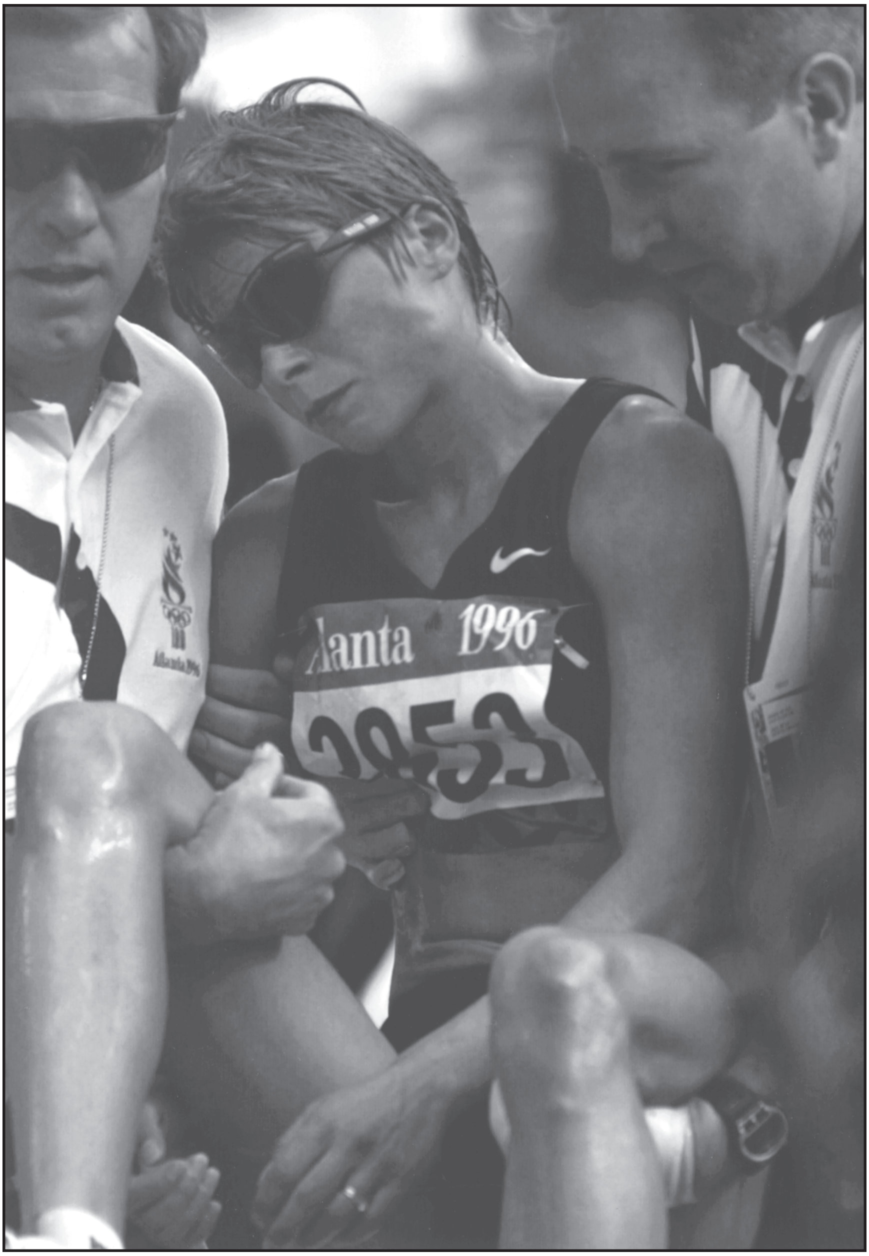

PHOTO 12.1—Anne Marie Lauck of the United States is carried from the track after the women's marathon in Atlanta, 1996 Olympic Games. Photo by Doug Mills, from AP/ Wide World Photos.

CHAPTER 12

HEAT AND HUMIDITY

Coaches and athletes need to appreciate several things about training and racing in conditions of high heat and humidity. The most important is that it can be dangerous. Training and racing in these conditions can cause heat cramps, heat exhaustion, and heat stroke. Generally, this level of distress does not arise when competing in events up through 1,500 meters, that is, unless it is a case of progressive exhaustion and dehydration over several days, as when conducting prelims, semis and a final. However, an athlete can fail to complete 3,000 meters in hot, humid weather conditions, and the risks are compounded in the longer distance events.

Heat Illness and Medical Emergencies

If an athlete shows signs of weaving about in a race, or otherwise becoming mentally disorientated, a coach is wise to act quickly. Do not wait to see the next lap, instead, pull the athlete off the course immediately. Failure to do so could result in a life-threatening situation. Alternately, the athlete's metabolism could be adversely affected, and the performances planned for the remainder of that athletic season could be compromised. Moreover, the athlete's future tolerance to hot and humid conditions could also become permanently impaired (Shapiro, et al., 1979).

Cool the individual down immediately, and if the available means are limited, first provide for the athlete's thirst, then cool the head, hands, feet and torso, in that order. If you are at a track and field facility and the steeplechase water hazard is filled, then go straightway for a dunk. Perhaps there is a hose available, or a shower facility nearby. Splashing or pouring water from a bottle can help, but this will not bring down elevated core temperatures as rapidly as will immersing the entire body in cool water. Sometimes an athlete can be directed to a cool shaded spot on the ground, and can then be soaked and briefly packed in ice. Obviously, fanning an athlete, or using an air conditioner can help to lower core temperatures, since much heat can be dissipated through respiration. In this regard, an automobile with air conditioning can provide on the spot assistance.

Heat illnesses include heat cramps (that is, muscle spasms induced by dehydration or loss of electrolytes), but also heat exhaustion and heat stroke. Heat cramps do not necessarily precede the onset of the latter two conditions, but with competitive athletes symptoms of heat exhaustion normally appear prior to the onset of heat stroke. Heat exhaustion is often caused by severe dehydration,

and the individual will commonly manifest signs of shock. Common symptoms of heat exhaustion and shock therefore include: dizziness, fatigue, headache, faintness, paleness, nausea, vomiting, goosebumps and even chills. Placing something cold on the back of the neck can reduce feelings of nausea and sometimes prevent vomiting. If you can get an athlete to lie down, and then prop up the legs—this can increase the effective blood volume to the vital organs and will often relieve symptoms of shock within 15 minutes. After a long distance race, athletes are generally dehydrated (needing of water), hypoglycemic (needing a simple form of sugar) and in need of both electrolytes and simple proteins.

Our normal core temperature is approximately 98.6° Fahrenheit, which corresponds to 37° Celsius. The core temperature of athletes competing in hot and/or humid conditions can climb to over 104° F (or 40° C), and they would then likely suffer symptoms of heat exhaustion or heat stroke. When the athletes' blood volume is sufficiently reduced due to severe dehydration, they may actually stop sweating, and this can result in a dramatic increase of their core temperature. In cases of heat exhaustion and heat stroke, core temperatures can rise to between 106° and 110° F (or 41.1° and 43.3° C), thus creating a potentially life threatening situation. Symptoms of heat stroke include mental disorientation, confusion, unconsciousness, seizure, and comma. When in doubt, do not delay. Heat stroke is a life-threatening situation that merits an immediate emergency 911 call and treatment by a trained medical professional.

Heat loss can be accomplished by radiation, conduction, convection, and evaporation. By estimate, evaporation can accomplish about 80% of an athlete's heat loss (Costill, 1986). During a marathon, the body produces approximately 2400kJ of heat, and under ideal conditions, a loss of approximately three liters of sweat through evaporation would provide adequate cooling (Newsholme, Leech, and Duester, 1994). However, a change of merely one percent (caused by loss of fluids relative to an individual's body mass) can disturb the body's thermoregulation, largely controlled by the hypothalamus. So the loss of three liters of fluid (or several pounds) by a 150-pound athlete through dehydration during a marathon is more than enough to cause potential problems (Newsholme, Leech, and Duester, 1994).

Perhaps the most difficult and dangerous situation is when athletes compete in conditions of high heat and humidity. For example, when the USATF National Championships are held in locations like Indianapolis or New Orleans, you can expect some casualties in the 5,000 and 10,000 meters. In hot and humid conditions, the athletes' sweat hardly evaporates and only provides a small cooling effect: They can be soaking wet with perspiration and nevertheless suffer heat stroke. Regardless of the environmental conditions, do not suppose that athletes will stop perspiring when afflicted with heat stroke. If an individual becomes disorientated or loses balance, coordination, or consciousness, then presume the situation is life threatening and obtain professional medical attention immediately.

The American College of Sports Medicine issued a position statement concerning distance races in 1975, and suggested that races with a distance of 16k/10 miles or greater should not be conducted when the wet bulb globe temperature exceeds 82.4° F or 28° C (Fox and Mathews, 1981). David Costill has similarly suggested that distance races of 10,000 meters and longer should not be conducted when the wet bulb globe temperature exceeds 82° F (Costill, 1986). This guideline should apply to any event above 1,500 meters, and be adopted as a rule at the high school, collegiate, and national level.

The Acclimatization Process

How can athletes properly prepare for conditions of high heat and humidity? No doubt, it helps if their genealogy can be traced to a location reasonably close to the equator, or to a location having a torrid climate. It is also advantageous if they have had long-term exposure, or prior experience with these climatic conditions in the past. Of course, if the athletes presently train in a similar climate, things are simplified. However, the difficultly comes when a major competition will be held in a location predicted to be hot and humid, and the athletes are not acclimatized to such conditions. Athletes need at least nine to 10 days to acclimatize to hot and/or humid conditions. However, if athletes put off acclimatization until the last nine to 10 days before the major competition, then the timing of this process will coincide with the nine-to-10-day worthwhile break and ascent to the desired time of peak performance. And with the exception of an under-distance time trial conducted three to five days prior to the competition, the athletes will not be performing hard work during the ascent. This scenario does not provide athletes with much practical experience, or the ability to judge their personal limitations when competing in these conditions.

Moreover, this acclimatization scenario introduces an undesirable stressor—that is, the burden of acclimatization—during the ascent to peak performance and thereby increases the training load at a time when just the opposite outcome is desired. Even with light or moderate training loads between 1/4 to 1/2-effort, recognize that nine to 10 days of acclimatization to heat and humidity will add at least an additional 1/4-effort to the overall equation. So athletes could unwittingly train at between 1/2 and 3/4-effort. This would completely defeat the purpose of the ascent preceding the major competition.

A more prudent course of action would be to include exposure to hot and humid conditions for a period of at least nine to 10 days during part of the sharpening period. The athletes could then carefully perform several of the 3/4-effort sharpening workouts. However, they should get away from hot and humid conditions for at least five to seven days and take care to recharge themselves (e.g., eat and drink properly, swim in cool water and avoid hot baths or saunas). In this way, they will become acclimatized and fully recover from the process. Thereafter, they should travel to the site of the competition and return to hot and humid conditions approximately seven to 10 days before the contest. They will then complete the acclimatization process, but now without undermining their

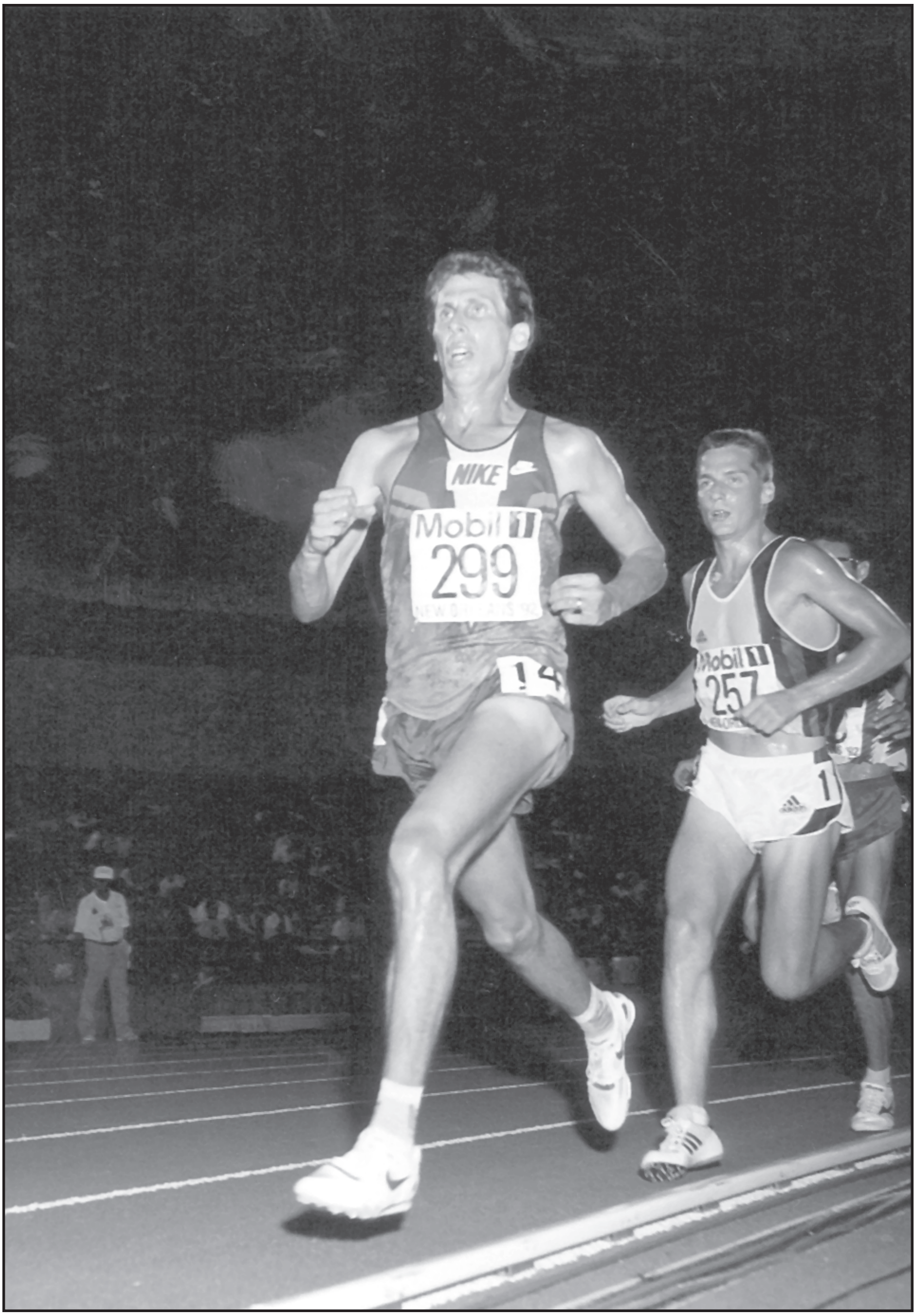

PHOTO 12.2—Steve Plasencia (left) and Todd Williams (right) contest one another, and the heat and humidity in New Orleans during the 10,000 meters at the 1992 Olympic Trials. Photo from Victah Sailer / Photorun.

PHOTO 12.3—PattiSue Plumer (left) and Sabrina Dornhoefer (right) battle during the 3,000 meters in Indianapolis at the 1988 U.S. Olympic Trials. Dornhoefer collapsed at the finish line. Photo from Victah Sailer / Photorun.

competitive prospects. The worthwhile break preceding the peak plateau will then be easy, and they will be able to attain peak fitness. Aside from the method just described, unless athletes live in a hot and humid climate or have several months of exposure to these conditions, generally they should not assume a more dramatic acclimatization program, or otherwise flog themselves with heat and humidity training. In the latter case, they would be more likely to hurt, rather than help themselves.

If athletes are going to run the marathon event in a major competition, the only prudent course is to opt for an extended period of exposure to such climatic conditions. Acclimatization can be accomplished in less time, but not sound judgment regarding how various temperature, humidity, sun, cloud, and wind conditions affect their performance. In the marathon, if an athlete's guess is off in one direction or the other by four seconds per mile, it can mean the difference between winning the race or blowing up at 18 miles. And inexperienced athletes will not normally recognize that they are in trouble until it is too late.

There are some general considerations that coaches and athletes should attend to during the preceding period of acclimatization. Since acclimatization is a stressor, athletes should:

- Get more rest
- Drink more fluids
- Eat more carbohydrates in the course of more numerous smaller meals
- Take Vitamin C and a multivitamin with trace minerals supplements—since these can be depleted at a higher rate with more profuse sweating
- Watch for a decrease in body weight
- Monitor urine for color
- Check for an increase in the morning pulse rate
- Take salt incrementally with meals

When, after hard exercise, athletes drink more and more water without the feeling of their thirst being satisfied, this is due to a lack of salt. They should drink cool water at a moderate rate after exercising, and then avoid any diuretics, such as coffee, tea, alcohol, or canned carbonated soft drinks (which can contain the same). Make sure to keep well hydrated in the days prior to a major competition.

During the last few weeks of acclimatization, do not introduce greater stress by wearing sweats during training, or sit in a sauna. These methods, and training during the hottest part of the day, can be used early in the preparation, or as an alternative to direct acclimatization, but do not overdo it. As always in training, introduce the stress of acclimatization gradually over time. An hour or two of exposure each day is all that athletes need. They do not have to train or sleep in an incubator.

Time and Travel

Air travel places additional stress on athletes. For one thing, the cabin pressure on most commercial aircraft corresponds to 5,000 feet of altitude. If athletes are

on a plane for the better part of one or two days, their metabolism can shift in the direction of acclimatizing to altitude. The cabin's air also tends to dehydrate passengers and crew. To get better quality air supply, it is advantageous to sit as far forward as possible. Following a plane trip, athletes should treat themselves as if they had been exposed to a hospital ward full of sick patients. Afterwards, as soon as possible, they should run for twenty minutes and take a shower. This will help stimulate their immune system and cleanse the lungs, sinuses, and skin.

Whenever possible, athletes should condition themselves to perform at the appointed hour of the competition. They need to be up and awake at least four hours before a competition. After rising, athletes should jog 15 to 20 minutes, then shower and eat breakfast. Many athletes eat a lighter than normal breakfast three to four hours before a competition. Try eating a normal breakfast sometime prior to a less important event and observe whether you have been cutting yourself short. Often, athletes find themselves a bit too hungry and actually too low on fuel when they eat a lighter than normal breakfast. Accordingly, sometimes it is best not to change your normal breakfast routine.

Travel across time zones presents a lot of other variables, but athletes can speed their recovery from jet lag by sticking to the new timetable on the first day. Light therapy can also be a great help. Athletes would do well to get up bright and early and to turn on every light available, but the quality of hotel lighting might not be sufficient. If possible, get outside for thirty minutes first thing in the morning and face the sun to take best advantage of the sunlight. Alternately, athletes might visit a sun tanning salon and take less than 15 minutes exposure to light therapy. However, make certain that the cooling fan normally provided is blowing, and wear a long sleeved shirt and pants to avoid receiving a sun tan or possible burn.

Heat, Humidity and Athletic Performance

When athletes are exposed to conditions of high heat and humidity their bodies will at first be a bit out of sorts. To provide for adequate cooling, blood must be diverted from working muscles to their skin. This decreases the oxygen available to the athlete's working muscles for performance, and thus effectively lowers their aerobic ability and anaerobic threshold. With acclimatization to heat and humidity: vasodilatation and cooling become much more efficient, the sweat response is faster and more robust, and blood plasma volume will increase. Athletes will then be able to perform well, but with diminished work capacity. Adverse climatic conditions always provide an opportunity, for those who know how to handle themselves correctly, to move up a bit relative to more talented athletes who do not.

Coaches and athletes also need to appreciate how much conditions of high temperature and humidity affect athletic performance at various competitive distances. To make an accurate estimate, you should always research the history of past athletic performances in similar conditions at the competition site. However, the following guidelines are provided for national caliber athletes competing at sea level in conditions equal to or greater than 70° F in combination with 70% humidity:

- There is no penalty to pay in events under 400 meters, and perhaps there is actually some advantage.
- In a single open 800 meters, the net effect is about zero, but with numerous preliminary heats, the practical effect will likely be a deficit of about two seconds.
- In the 1,500 meters, such conditions are worth a deficit of about four seconds.
- In the 3,000 meters, the deficit is about eight to 10 seconds.
- In the 5,000 meters, the deficit is about 20 seconds.
- In the 10,000 meters, the deficit is in the range of 60 to 80 seconds.
- In the marathon, the deficit is in the range of four to six minutes.

These guidelines are conservative and presume that athletes have acclimatized and prepared properly. Note that the deficits increase geometrically in relation to distance. Circumstances alter races, thus athletes should always reassess environmental conditions immediately prior to, and during the course of a competition.

Conduct on the Day of Competition

In conditions of high heat and humidity, athletes need to conduct themselves prudently on the day of competition. Consider taking the following positive steps: stay out of the heat and away from the sporting arena as long as possible; bring shade such as a light colored tent or umbrella; bring more ice water than needed and plan to sip a pint every fifteen minutes; bring several bags of ice in a cooler; locate a nearby shower facility; and, bring light colored clothing. Once exposed to the stressful environmental conditions, it is hardly possible to keep up with the need for rehydration. At the same time, beware of overdrinking out of nervousness, since you would then be constantly running to the bathroom and triggering an alarm reaction that would further tax your endocrine system.

As opposed to a conventional warm-up, athletes can actually benefit from a cool-down, completed about 30 minutes before the major contest. Despite their best efforts to minimize exposure on the day of competition, athletes will likely face the undesirable climatic conditions for several hours—that is, given the logistics associated with travel to the site, check-in, and so on. That being the case, whenever possible, they are well advised to take a cool, but not cold, shower as close as possible to race time, while still allowing adequate time to conduct a brief warm up. This will go a long way to rehydrate and freshen-up athletes for the coming event. Generally, in hot and humid climate conditions, a proper warm-up requires less than 30 minutes.

Normally, athletes should avoid electrolyte fluid replacement drinks during competition unless they have prior experience and control over the contents of the drink. Further, most commercially available electrolyte drinks need to be greatly diluted to be suitable for runners. Otherwise, the drink may later end up on

their racing shoes and the pavement. The use of electrolyte fluid replacement drinks can be advantageous during the process of acclimatization and in the days prior to a major event, but on race day the prudent advice is—go with water. However, if the athletes will be competing in an ultra-distance event in torrid conditions, then they clearly need to perfect the contents of their electrolyte drink in the months prior to the competition.

In conditions of heat and humidity, do not be fooled by cloud cover, because it does not substantially reduce the need for hydration. And beware of prevailing winds in the presence of high temperatures since they can cause more rapid dehydration. Also, the energy lost when struggling against a headwind is not fully compensated for by a tailwind. Moreover, recognize that a headwind has an increased cooling effect, whereas a tailwind decreases the cooling effect.

Proper Equipment

The racing singlet should be white, and include relatively fine open mesh panels on the lower front, sides and back. The material should neither retain sweat so as to become heavy and sag, nor be incapable of saturation. Instead, a happy medium needs to be struck. Sometimes a light natural cotton fiber works well. Beware of many synthetic materials, and always first test a singlet under the conditions you expect to encounter. Many of the new so-called high technology synthetic fibers, which are supposed to breathe and do other sophisticated things, do not perform well in practical application. Let the buyer beware. Do not believe what you are told. Take the singlet with the wonder material and soak it in the sink, then check its weight when wet. Put it on and go for a run to see how long it takes to dry, and how it actually behaves on your body. Use the singlet in hot and humid conditions to be certain what it will do. Believe what you see, and what you know to be true after experimentation.

Athletic shorts should also be light colored, but not white, out of considerations of modesty, since they will likely become soaked and somewhat transparent. Make certain that the waistband is not too tight because this can restrict full respiration. Another restriction in the modern design of male athletic shorts is their inner liner, which functions much like an athletic support, not permitting the male private parts to be suspended in a natural manner. While good from the standpoint of modesty, this restriction can reduce heat dissipation. Further, abnormally high or low temperatures in this region can send the wrong message to the hypothalamus and trigger inappropriate physiological responses affecting temperature regulation. So, while not advising exhibitionism, male athletes might want to reconsider the extremely short, tight athletic shorts with restrictive inner liners that are most prevalent at the present time. Only in the last twenty-five years have athletic shorts with this kind of configuration become popular. The author's attempt to address these problems can be found in several granted utility patents (U.S. 6,243,879, U.S. 6,243,880, and U.S. 6,353,940).

Proper socks are a critical piece of equipment, especially when competing in the marathon. Thin socks with favorable qualities *vis-á-vis* heat dissipation and abrasion are best. The choice depends somewhat on the nature of the insole, but

also the inside of the shoe upper. Figure out the shoe and sock combination well in advance and then have two spares of each available.

Many road racing shoes made at the present time have relatively thick, unbreathable uppers. To improve breathability, you can cut out portions of the sides, and punch holes in the central area of the forefoot of the shoe upper. Strip out the foam backing in the tongue, and replace the laces with water resistant ones. However, take care not to weaken the support structure of the shoe, or to do anything that will cause blisters. The spring stiffness and dampening performed by the soles of various footwear (and their thermal conductivity) are not all the same. Further, realize that dampening generates heat. Some light-weight shoes actually have foam midsoles that are too soft for many athletes. Such shoes may be light and provide good protection from shock loading, but can provide too soft a spring for effecting optimal performance. And high temperatures will tend to render the cushioning materials even softer. Efficiency is important in all distance events, but it is absolutely critical in the marathon.

Once again, how much do the athlete's racing shoes weigh? In this regard, you may wish to review Chapter 10, which discusses the effect of shoe weight and mechanical efficiency on athletic performance. Consider how conditions of high heat and humidity could influence the performance of athletic footwear. Whenever in doubt, *always* conduct a prior evaluation. Consider the worst-case scenario. If it rains, does the outsole afford good traction? In this regard, much is determined by the design and wettability characteristics of the outsole. Does the shoe or sock soak up moisture and then become much heavier? Does the shoe become too hot with prolonged running? Assume nothing and conduct appropriate experiments to find out what you need to know. Again, at least three months before a major competition, the athlete needs to select and start training in the correct shoe.

The human head can provide a major source of heat loss. A hat worn to shade dark hair from the sun must be of a kind that will not appreciably reduce heat loss. And unless athletes will be staring into the sun, they should avoid using sunglasses. Fashionable sunglasses have become popular with some elite athletes, since they are being compensated for wearing the products. While this may make some athletes *look* cool, it does not help them to *stay* cool. After athletes have completed a hard run, the area about their eyes will often appear to glow red. Accordingly, it is unwise to shield this area and reduce its ability to radiate and dissipate heat. The hands and feet can also provide substantial heat loss, thus cooling these areas as much as possible during a race can also positively influence an athlete's performance.

Race Conduct

Athletes should be conservative in the early pacing under conditions of high heat and humidity. They should treat the situation much as though they were running at altitude, or had suffered from a slight illness in the week prior to the competition. Since climate conditions then effectively diminish their aerobic ability and anaerobic threshold, athletes should not only be conservative in their energy use

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(12) **United States Design Patent**
Lyden

(10) **Patent No.:** **US D467,055 S**
(45) **Date of Patent:** ** **Dec. 17, 2002**

(54) **ATHLETIC SHORTS**

(76) Inventor: **Robert M. Lyden**, 18261 SW. Fallatin Loop, Aloha, OR (US) 97007

(**) Term: **14 Years**

(21) Appl. No.: **29/144,574**

(22) Filed: **Jul. 6, 2001**

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(51) **LOC (7) Cl.** **02-02**
(52) **U.S. Cl.** **D2/738**
(58) **Field of Search** D2/711–713, 731–732, D2/738, 742, 745; 2/400–408, 228, 236–238, 78.1, 78.2, 78.3, 76, 109, 110

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Primary Examiner—Louis S. Zarfas
Assistant Examiner—Robert A Delehanty
(74) *Attorney, Agent, or Firm*—Westman, Champlin & Kelly, P.A.

(57) **CLAIM**

The design for athletic shorts, as shown and described.

DESCRIPTION

FIG. **1** is a front view of athletic shorts embodying my new design;
FIG. **2** is a right side view thereof, the left side being a mirror image of the right side view;
FIG. **3** is a rear view thereof;
FIG. **4** is a top view thereof; and,
FIG. **5** is a bottom view thereof.
The broken lines showing of interior environmental structure of the shorts in FIGS. **4** and **5** of the drawing views form no part of the claimed design.
The crosshatch shading shown in the drawings is understood to indicate fabric.
The area of the waistband including vertical lines indicates the inclusion of elastic material, and the area of the waistband devoid of vertical lines indicates the inclusion of non-elastic material.

1 Claim, 3 Drawing Sheets

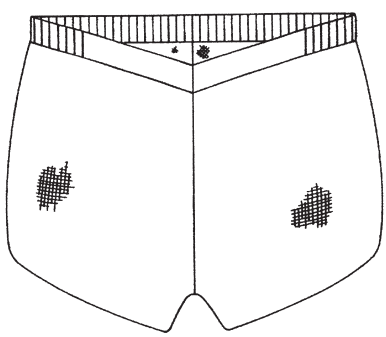

FIGURE 12.1—U.S. Design Patent 467,055

early on, but also as the race progresses. For example, an athlete would not be well advised to attempt numerous attacks in the form of surges or breakaways, but rather to make one decisive move when the opponents are vulnerable.

Recovery from Competition

Immediately after a race, athletes should drink cool, but not cold water. After hard exercise, it is normally not good to shock the overheated body with ice water. Accordingly, unless they suffer from heat exhaustion or heat stroke and face a medical emergency, athletes should not gulp down ice water or jump into cold water immediately after a workout or race. After taking some water, they should consume a citrus juice that includes a simple sugar such as pineapple-grapefruit juice, or a commercially available electrolyte and energy replacement drink. Athletes should then conduct a brief cool down lasting five to ten minutes, and finish by stretching while still warm. At that point, a cool shower or dip in a pool will do no harm.

If a meal is over an hour away, athletes should consume some additional carbohydrates with a high glycemic index such as glucose, fructose, honey, or bread, but then follow up with carbohydrates having a moderate glycemic index. A natural yogurt culture with fruit can sometimes help replace bacteria killed by high core temperatures, and also provide needed carbohydrates and protein. Generally, athletes find they can better digest smaller, more frequent meals in hot and humid conditions.

Upon arrival at a hotel, athletes should maintain the room at a moderate temperature, and perhaps cool it down over the period of an hour. Later in the evening, it may be possible to take an easy swim. Before going to bed, it is advisable to sit in a bathtub with several bags of ice packed above and below each leg. Despite any initial discomfort, packing the quads, hamstrings, and calves for 20 minutes in this manner will dramatically accelerate recovery. This procedure should be observed in the evening following competition whenever qualifying rounds are being undertaken.

When all is said and done, preparation for heat, humidity, and travel is just another training task. Athletes should not attach too much to the task, since that can disturb proper focus. Do not make it out to be more than what it is. Simply do what has to be done to prepare, and then forget about it. If worrisome thoughts should arise such as, “I wonder if I drank enough”—well, simply check to see that you have, and if so, do not further attach to the thought. Rather, simply let it go. Stay in the NOW.

> ***When I look back on all these worries, I remember the story of the old man who said... that he had a lot of issues in his life, most of which never happened.***
>
> —Winston Churchill

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PHOTO 13.1—Kip Keino winning the 1,500 meters, 1968 Olympic Games. Photo by E.D. Lacey, from George Herringshaw & sporting-heroes.net.

CHAPTER 13

ALTITUDE TRAINING

Altitude training first became a pressing topic of interest in track and field in connection with the 1968 Olympic games. Mexico City is at an altitude of 7,400 feet, and has a barometric pressure of only 580 mm of mercury, compared to 760 mm of mercury at sea level (Sparks and Bjorklund, 1984). This decrease of in ambient air pressure (approximately 23.5%) also meant a corresponding drop in air density. The lower air density reduced aerodynamic drag and provided a 1.7% improvement of performances in the sprint events (Ward-Smith, 1984). Certainly, the decrease in air density also aided performances in the jumping events: Bob Beamon's World Record in the long jump stood for over 20 years. Italy's Pietro Mennea's World Record at 200 meters was also set in Mexico City, and lasted from 1979 to 1996. However, the lower air pressure and density adversely affected performances in predominantly aerobic events. Performances in the 1,500 meters decreased by about three percent, or seven seconds. In the 5,000 meters, they suffered by about eight percent, or one minute. And in the 10,000 meters, they suffered by eight percent, or 2:30 (Sparks and Bjorklund, 1984). Athletes who were born, raised, and trained at altitude, such as Kip Keino of Kenya, had a substantial advantage, as did athletes who had acclimatized for performance at altitude.

Race Distance	Performance at Sea Level	Performance With 3% Altitude Adjustment
Men's 1,500m	3:40.5	3:46.6
Women's 1,500m	4:18.5	4:26.2
Men's 3,000m SC	8:42.0	8:57.6
Women's 3,000m SC	10:38.0	10:57.1
Men's 5,000m	13:47.0	14:11.8
Women's 5,000m	16:05.0	16:33.9
Men's 10,000m	28:50.0	29:41.9
Women's 10,000m	33:20.0	34:20.0

TABLE 13.1—2000 USATF Outdoor Qualifying Standards

Athletic Performance and Altitude

Coaches and athletes need to know how much altitude will affect performance in any given event. Table 13.1 provides the 2000 USATF outdoor qualifying standards, including a 3% allowance for events of 1,500 meters or longer, when contested in a facility at 4,000 feet or more. In addition, see Table 13.2 and Figure 13.1, which were created by Jack Daniels (Daniels, 1975, and 1979). Daniels is one of the most knowledgeable individuals in the United States on this subject, and an excellent coach. If you have a question about some aspect of altitude training not addressed in this chapter, the author suggests that you contact him through Cortland State University in the State of New York.

Race Tactics and Altitude

When runners compete at altitude, as in conditions of high heat and humidity, their aerobic ability and anaerobic threshold will be effectively decreased. A correct initial determination of race pace is therefore essential. Runners are wise to begin conservatively and to maintain an even pace they can sustain. Often, athletes who have done their homework will hang well behind in the first quarter of the race and not get into the thick of things until the third quarter. But at that point, they will pass numerous casualties who have misjudged their fitness and the conditions. Runners should not engage in numerous surge and breakaway attempts. They should take advantage of drafting the lead runners or pack, and then make a decisive move when the opportune moment arrives—or quickly cover the move of a competitor, and then finish with a well timed kick.

Athletic Performance and Moderate Altitude

Coaches and athletes often make the mistake of presuming that the altitude effect is not present when they travel to competitions at moderate altitude, such as three thousand feet above sea level. This is a grave mistake. It is there and athletes had better respect it.

Acclimatizing in Order to Compete Successfully at Altitude

Coaches and athletes need to know a few basic things about acclimatizing in order to race successfully at altitude. Several prescriptions are provided below to address the most probable scenarios coaches and athletes might encounter:

Scenario 1: Same or Next Day Competition at Altitude

If you face the prospect of having to travel to altitude and race without a period of acclimatization, then travel to the site as close to the time of competition as possible. If an overnight stay is necessary prior to a morning competition, then leave late on the day before. Eat lightly that evening and the next morning. Use as little energy as possible in order to maintain a slow metabolic rate. Do not conduct a long warm-up or go out fast in the race, but rather be conservative in the early going (Dales, 1997). This can apply to many other collegiate and professional sports. The athlete should fly into altitude either the night before or the day of the contest and compete directly—that is, if it is not possible to allow for at least five, and preferably nine to 10 days of acclimatization.

TIME LOSS FOR RACES
OF DIFFERENT DURATION AT DIFFERENT ALTITUDES

Race Duration Sea Level	Altitude 1,000 m (3280 ')	Altitude 1,500 m (4921 ')	Altitude 2,000 m (6561')	Altitude 2,250 m (7382')	Altitude 2,500 m (8202')
3 min	0:00.2	0:01.0	0:01.4	0:02.5	0:04.0
4 min	0:00.5	0:01.8	0:02.4	0:04.1	0:05.8
5 min	0:00.7	0:02.4	0:03.6	0:07.2	0:09.0
6 min	0:01.0	0:03.3	0:05.0	0:09.0	0:12.2
8 min	0:01.8	0:05.5	0:09.6	0:15.4	0:20.1
10 min	0:02.7	0:07.9	0:14.4	0:21.8	0:28.1
12 min	0:04.0	0:10.8	0:19.4	0:28.2	0:36.1
14 min	0:05.5	0:13.8	0:24.6	0:34.6	0:44.1
16 min	0:07.0	0:16.8	0:29.8	0:41.0	0:52.1
18 min	0:08.5	0:19.8	0:35.1	0:47.5	1:00.2
20 min	0:10.0	0:22.8	0:40.8	0:54.0	1:08.4
25 min	0:15.0	0:32.0	0:56.3	1:13.5	1:30.0
30 min	0:20.2	0:41.5	1:12.9	1:32.0	1:52.0
35 min	0:25.8	0:51.7	1:29.2	1:51.5	2:15.0
40 min	0:32.2	1:03.6	1:46.1	2:12.0	2:40.0
50 min	0:45.0	1:27.0	2:22.5	2:52.5	3:28.0
60 min	1:00.0	1:52.0	3:00.0	3:36.0	4:17.0
1.5 hr	1:45.0	3:10.0	5:00.0	5:47.0	6:50.0
2.0 hr	2:30.0	4:30.0	7:00.0	8:00.0	9:30.0
2.5 hr	3:30.0	6:00.0	9:10.0	10:30.0	12:15.0
3.0 hr	4:30.0	7:30.0	11:20.0	13:00.0	15:00.0

The table has been calculated for acclimatized athletes and the values provided should be added to the relevant sea level performances. Note: Unacclimatized athletes might lose up to twice the projected correction for altitude depending on the pace, terrain, and conduct of the competition.

TABLE 13.2—Adapted from Daniels, 1975

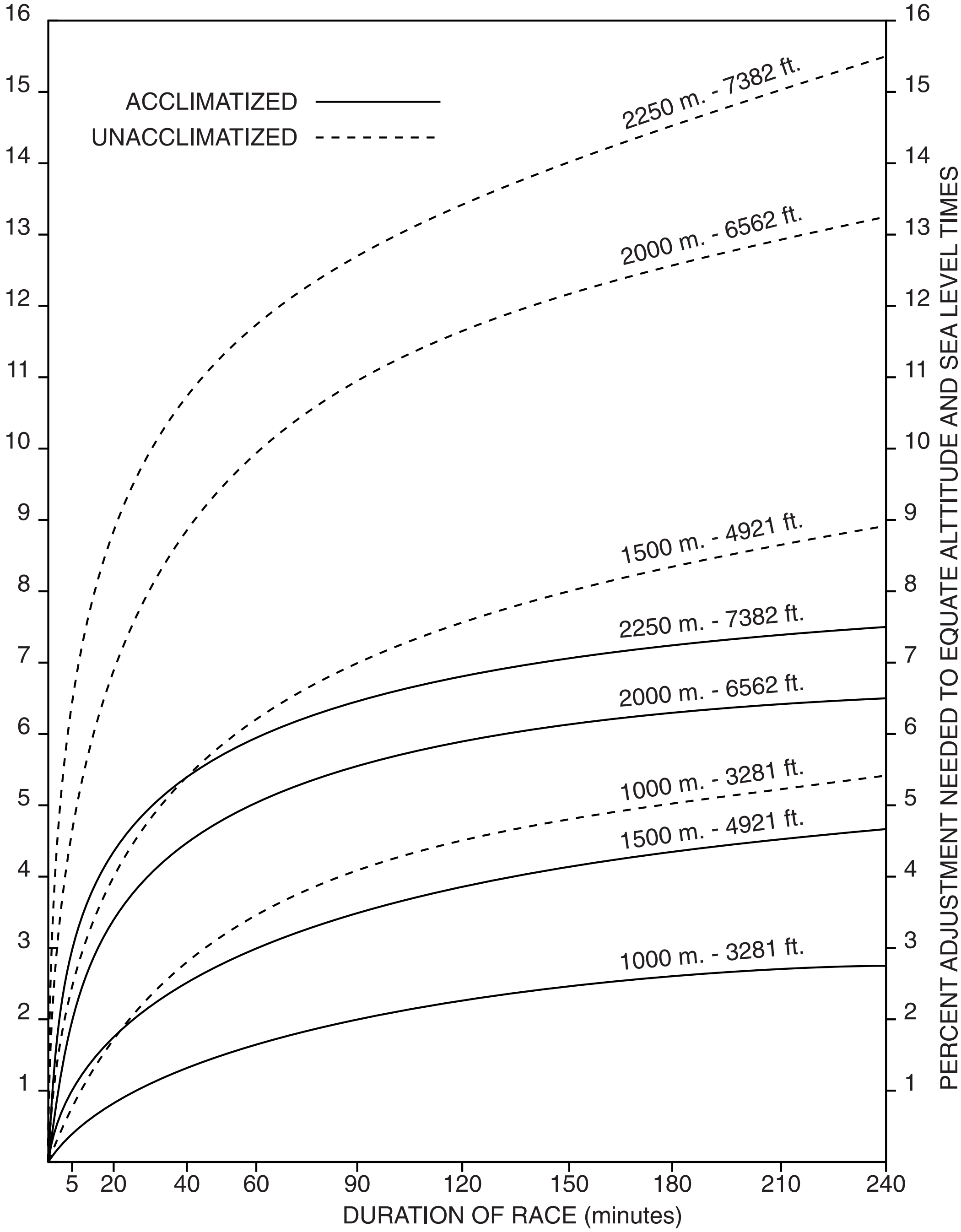

FIGURE 13.1—Adapted from Daniels, 1979

Scenario 2: When at Least 9-10 Days Are Available to Acclimatize

If a more extended period of acclimatization is possible, athletes should allow at least nine to 10 days to adjust. The acclimatization process does not advance to a substantial degree in the first 24 hours so as to dramatically compromise their working capacity. If athletes want a taste of what they will feel like when racing at altitude, then the first day is the time to do it. From purely a physiological standpoint, the athletes would not be well advised to conduct a workout or time trial at more than 1/2-effort in the first or second day, since a hard effort in the early days of exposure to altitude can cause an exercise-induced decrease in erythropoeitin and other adverse reactions that can hinder the acclimatization process (Berglund, 1992). However, if the athletes exert a hard effort anyway, much more can be gained in the domain of cognitive learning and mental callusing—and these will have a greater positive affect upon later performance at altitude. In particular, inexperienced athletes need to use the first or second day to find out how difficult racing at altitude will be (Daniels, 1984-1997). The altitude will impair their working capacity, but their metabolism will not yet be out of kilter from the changes soon to take place during the acclimatization process. Remember that normal cabin pressure in air travel effectively exposes athletes to the equivalent of about 5,000 feet of altitude. So athletes should start counting hours of exposure the minute the aircraft leaves the ground.

In an extended period of altitude acclimatization, the athlete's performance capability will most dramatically suffer between the first 24 through 72 hours of exposure. Thereafter, they will progressively improve as acclimatization continues through the ninth to 10th day. The morning pulse can be a good indicator of their progress. Figure 13.2 shows a typical heart rate response over the days of acclimatization.

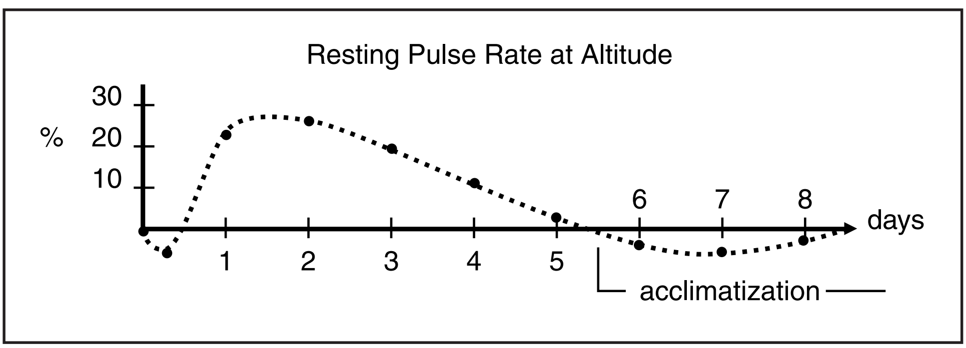

FIGURE 13.2—from Berghold, 1982

Scenario 3: When at Least Two Periods of Exposure to Altitude are Possible

Just as when acclimatizing to heat and humidity, athletes need to consider the increased workload imposed by altitude. Prior to a major competition at altitude, it is prudent to begin the acclimatization process prior to the nine-to-10-day worthwhile break leading to the seasonal peak performance. During this time, athletes normally decrease their training loads to less than 60% of their working capacity, and acclimatization would add at least 25% to the equation. Just as with heat and humidity, the additional training load imposed by acclimatization at this time would compromise the worthwhile break and suppress the ascent to peak performance. Instead, athletes should first acclimatize to altitude over a period of least nine to 10 days, then get away from altitude for not more than two to three weeks (so as not to lose substantial acclimatization), then return to altitude nine to 10 days prior to the competition. This way, the second period of exposure will not impose so substantial a workload on the athletes or suppress their potential performance.

Scenario 4: When an Extended Stay at Altitude is Possible

Athletes might seek to more fully acclimatize and compete at altitude, or to enhance their performance potential at sea level by exposure to altitude. In this case, a more lengthy stay at altitude is necessary. When athletes move from sea level to an altitude of 2,500 meters, then about 12 weeks of exposure to altitude is enough to fully acclimatize. Hemoglobin levels in athletes are commonly 50% higher than in sedentary individuals, but hemoglobin differences for individuals living at 2,500 meters are normally about 12% higher than those living at sea level, and athletes only gain about 1% for each week of exposure to altitude (Berglund, 1992).

J. A. Faulkner suggested an innovative training method (Faulkner, 1966), and Jack Daniels and Neil Oldridge subsequently proved it: athletes can enhance training by alternating two to three weeks of exposure to altitude with a week of training at sea level over an extended period of time (Daniels and Oldridge, 1970). Athletes can then conduct quality anaerobic work and performances at sea level and maintain a balanced training program. In fact, this can be an ideal way for distance runners to train. Flagstaff, Arizona, and Lake Tahoe, California, both provide athletes with the ability to train at altitude and yet escape from it periodically in less than two hours of driving time (Daniels, 1984 -1997). Further, the practice suggested by Daniels and Oldridge of alternating exposures to altitude and sea level would also tend to avoid training habituation and resulting stagnation. However, keep in mind that the harder the athletes train at altitude, the sooner they will need a worthwhile break.

Starting in the 1960's, many athletes began to use altitude training not only to compete to good effect at altitude, but also to aid their performances at sea level. To understand the principles behind this method, we need to look briefly into the physiology of acclimatization to altitude.

The 23.5% decrease in air density at 7,400 feet of altitude in Mexico City basically means that a liter of air has 23.5% fewer molecules of all the gases normally contained in ambient air. The same ratio of oxygen is still present, but there is 23.5% less of it, as well as the other gases, because of the reduced atmospheric pressure. The concentration of oxygen relative to the other atmospheric gases does not significantly decline until the elevation exceeds 10,000 feet.

In supercharging an automobile, the gas mixture injected into the combustion chamber is commonly pressurized between one to five psi—thus more molecules of fuel are packed into the confines of the combustion chamber prior to ignition. This illustrates what happens when athletes puff their cheeks and purse their lips while exhaling—they are placing backpressure on their lungs and performing the work of a supercharger.

At altitude, because there is less oxygen in each breath of air, athletes initially make up the difference by breathing more frequently. In fact, they will tend to hyperventilate, and this can lead to dizziness and nausea. Hyperventilation or a higher respiratory rate will expel higher than normal amounts of carbon dioxide, and this influences the acid-base balance of the body. The blood then becomes more alkaline, that is, it has a higher pH. Over time, this can reduce their ability to perform and use anaerobic power.

Altitude training can negatively impact preparation for the sprint events up through 800 meters, since these events primarily use anaerobic metabolism. Training at altitude can also compromise an athlete's ability to conduct quality-sharpening work in the longer distance events. This potential liability can be dealt with given the following training practices: maintain the desired goal pace when conducting shorter interval workouts at altitude, but simply take longer than normal recoveries. When running longer repetitions, shorten their length relative to sea level, and also provide extended recovery periods.

Altitude training also dehydrates athletes, but somewhat imperceptibly, since the air is much drier at higher elevations. Athletes will need to make doubly sure they are sufficiently hydrated, because they may not have the usual cue of profuse sweating to indicate the amount of dehydration. The most dramatic effect of altitude training is that it stimulates the production of more red blood cells, hemoglobin, and myoglobin, thus increasing the oxygen-carrying capacity of the blood and working muscles. Given a lengthy exposure to altitude, the number of mitochondria and capillaries present in muscle tissue will also increase.

Clearly, altitude training is not a bed of roses. The time, energy, expense and logistics of travel and dislocation must be considered. And there is something to be said about Percy Cerutty's criticism of altitude training. He found that there can be as much or more to gain by learning to breathe more deeply and fully as there is by going to altitude (Cerutty, 1970's). The pulmonary function of elite distance runners is greater than that of the average population (Martin, May, Pilbeam, 1986).

PHOTO 13.2—Karl Keska running in his native England. Photo courtesy of Karl Keska.

Nevertheless, in studying the careers of successful distance runners, altitude training clearly stands out as an important factor. It is a tool that can help athletes progress to the next level. And once they have attained a new level, their acquired performance potential does not evaporate if they decide to move away from altitude. True, they will lose the extra edge provided by additional hemoglobin and red blood cells, but not their fundamental performance capability. Steve Plasencia, a nationally ranked distance runner in the United States for over a decade, moved from Minnesota after college to live and train in Eugene, Oregon (419 feet). However, he would often conduct altitude training in Flagstaff, Arizona (7,000 feet) or Boulder, Colorado (5,400 feet) prior to a major national or international competition. Karl Keska, a graduate of the University of Oregon, also used a well-timed exposure to altitude in Boulder, Colorado prior to delivering his personal best performance for 10,000 meters at the 2000 Olympic games.

Racing at Sea Level After Descending from Altitude

Distance runners should come down from altitude and compete in the main event within the first three days of exposure to sea level. Athletes can race well on days one to three, but day four can be questionable, and by day five their performance will invariably suffer (Koch, 1999). Daniels relates that Jim Ryun descended from altitude and set the world record in the mile the next day (Daniels, 1984 -1997). Elite athletes in the long distance events sometimes feel that several days of exposure to sea level helps to re-adjust their respiratory rate. It may be an advantage to first conduct the under-distance time trial that is used to set up the athletes for a competition three to four days prior to the main event, and then

descend to sea level and compete in the main event within a three-day period. Alternately, national and world-class athletes can descend and time trial at sea level approximately 72 hours prior to the main event.

Descending from Altitude When Acclimatizing to Heat, Humidity, or Time Change

Timing can be critical when athletes need to descend from altitude at an early date to prepare for a major competition at sea level. This is sometimes necessary when athletes train at altitude in relatively cool and dry conditions, but must acclimatize for competition in hot or humid conditions. Sometimes this is also necessary when they must travel extensively and adapt to a change in time zones. Research and practical experience suggest that upon descending from altitude, athletes will enjoy a favorable period of performance during the first three or four days. Then their performance capability regresses markedly until about the ninth or 10th day. Thereafter, their fitness will improve and can reach a second optimal period for performance between the 18th and 22nd day. Their fitness level will then gradually decline (Suslov, 1994, and Popov, 1994). This is the common perception of athletes who train at altitude and frequently race at sea level. Many variables could account for these findings. To understand which physiological changes are responsible, more controlled research studies need to be done.

The common perception is that the first window of opportunity, between days one and three, is superior to the second, between the 18th and 22nd day. But the latter option is best when athletes must also acclimatize to heat and humidity. Athletes might then consider the following: It can be advantageous to descend from altitude during the early part of the worthwhile break in the middle of the sharpening period. This places the move from altitude to sea level during a week of low training loads and enables them to compete at sea level in the scheduled weekend competition. They could then remain at sea level for the second seven-to-10-day work meso-cycle of the sharpening period and conduct the last two or three 3/4-effort sharpening sessions, which normally comprise repetition workouts. They could recover from the last repetition workout over four to six days, then conduct an under-distance time trial or race three to four days before the major competition.

Altitude and the Advent of Artificial Performance Aids

It did not take long for those interested in exercise physiology to figure out that they could collect an athlete's red blood cells, plasma, or whole blood, and then preserve it for re-infusion at a later date. Shortly before a major competition, a portion of the blood would then be re-infused, and the athlete's performance could be considerably enhanced (Williams, 1981). This was called "blood boosting" or "blood doping," and it was done with Eastern Block distance runners as early as the 1960's. Blood doping permitted athletes to obtain some of the benefits of altitude training without the logistical problems of traveling and training at altitude several times during the months before a major competition. At the same time, the athletes were also able to conduct quality sharpening and anaerobic work at sea level. However, some athletes are believed to have died from complications associated with the procedure.

PHOTO 13.3—Igor Gamow, Associate Professor of Chemical Engineering at Colorado University, holding an altimeter inside a prototype altitude bed. Photo by Ken Abbott, Colorado University, and courtesy of Igor Gamow.

This method of doping became obsolete with the widespread availability of DNA-recombinant erthropoietin (RhEPO) as a prescription drug. The hormone erthropoietin is normally secreted by the kidneys in response to reduced oxygen in the body tissues, and it triggers the production of red blood cells. Unfortunately, there is no shortage of doctors willing to prescribe this substance for athletes. The use of RhEPO has also caused the death of numerous athletes. The blood can become too thick and viscous, thereby causing congestive heart failure. Athletes using RhEPO have taken still other drugs to thin their blood and reduce its ability to coagulate. However, a side effect of these drugs is that they can promote hemorrhaging.

The governing bodies in cycling and cross-country skiing have responded to the recent deaths by implementing pre-race tests of the athletes' hematocrit and hemoglobin. The normal hematocrit for males is approximately 47, plus or minus seven percent, thus a value slightly over 50 would not be judged abnormal (Jacob and Francone, 1974). In 1997, the *Union of Cycliste Internationale* (UCI) established a hematocrit limit of 50 for male athletes. If cyclists test over 50, then they are simply not allowed to compete since it is not considered safe. Some criticize this limit as being too low and likely to result in false positives (Martin, Ashenden, Parisotto, Pyne, Hahn, 1997). In 1996, the International Ski Federation (FIS) established a hemoglobin limit of 16.5 and 18.5 for female and male